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# Electrical properties and microstructure of ternary Ge/Ti/Al ohmic contacts to p-type 4H-SiC.

## Dialog eLinks

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## Author(s)

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## Abstract

The high-power SiC devices require ohmic contact materials, which are prepared by annealing at temperatures lower than 800°C. Recently, we demonstrated in our previous paper (J. Appl. Phys. 95, 2187 (2004)) that an addition of a small amount of Ge to the conventional binary Ti/Al contacts reduced the ohmic contact formation temperature by about 500°C, and this ternary contacts yielded a specific contact resistance of approximately  $1 \times 10^{-4} \Omega \text{ cm}^2$  after annealing at a temperature as low as 600°C. In this paper, the electrical properties and the microstructures of the Ge/Ti/Al contacts (where a slash "/" indicates the deposition sequence) were investigated by current-voltage measurements and transmission electron microscopy observations, respectively, in order to understand the ohmic contact formation mechanism. Ti/sub 3/SiC/sub 2/ compound layers (which were previously observed at the metal/SiC interface in the Ti/Al ohmic contacts after annealing at temperatures higher than 1000°C) were observed to grow epitaxially on the SiC surface after annealing at temperatures as low as 600°C. The Ti/sub 3/SiC/sub 2/ layers were believed to act as a p-type intermediate semiconductor layer, which played a key role to reduce the Schottky barrier height at the contacting metal/SiC interface. Further reduction of the contact resistances of the Ge/Ti/Al contacts would be achieved by increasing the coverage of the Ti/sub 3/SiC/sub 2/ layers on the SiC surface.

## Descriptors

ALUMINIUM; ANNEALING; CONTACT-RESISTANCE; CRYSTAL-MICROSTRUCTURE; GERMANIUM; OHMIC-CONTACTS; SCHOTTKY-BARRIERS; SEMICONDUCTOR-METAL-BOUNDARIES; SILICON-COMPOUNDS; SURFACE-MORPHOLOGY; TITANIUM; TRANSMISSION-ELECTRON-MICROSCOPY; WIDE-BAND-GAP-SEMICONDUCTORS.

## Classification codes

A7340N Electrical-properties-of-metal-nonmetal-contacts\*;  
A7330 Surface-double-layers-Schottky-barriers-and-work-functions;  
A6480G Microstructure;  
A6170A Annealing-processes;  
A7340C Contact-resistance-contact-potential-and-work-functions;  
A6820 Solid-surface-structure;  
B2530D Semiconductor-metal-interfaces\*;  
B2520M Other-semiconductor-materials;  
B2550A Annealing-processes-in-semiconductor-technology.

## Keywords

electrical-properties; microstructure; Ge-Ti-Al-ohmic-contacts; p-type-SiC; annealing; contact-resistance; transmission-electron-microscopy; Ti/sub-3/SiC/sub-2/-compound-layers; metal-SiC-interface; Schottky-barrier; TEM; surface-morphology; semiconductor-metal-boundaries; 800-degC; 500-degC; 1000-degC; 600-degC; Ge-Ti-Al-SiC; SiC.

## Treatment codes

X Experimental.

**Numerical indexing**

temperature: 1.07E03 K.

temperature: 7.73E02 K.

temperature: 1.27E03 K.

temperature: 8.73E02 K.

**Chemical indexing**

Ge-Ti-Al-SiC-int, SiC-int, Al-int, Ge-int, Si-int, Ti-int, C-int, SiC-bin, Si-bin, C-bin, Al-el, Ge-el, Ti-el.

SiC-sur, Si-sur, C-sur, SiC-bin, Si-bin, C-bin.

**Language**

English.

**Publication type**

Journal-paper.

**Availability**

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## Development of ohmic contact materials for wide gap p-type 4H-SiC.

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**Conference information**

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**Source**

2003 International Semiconductor Device Research Symposium (IEEE Cat. No.03EX741), 2003, p. 334-5, 6 refs, pp. xxiii+537, ISBN: 0-7803-8139-4. Publisher: IEEE, Piscataway, NJ, USA.

**Author(s)**

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**Abstract**

Conventional TiAl ohmic contacts are annealed at a high temperature which caused extremely rough surface morphology. The objective of this paper is to reduce the annealing temperature of the ohmic contact formation by adding a thin Ni or Ge layer to the TiAl contacts. The microstructure analyses between the SiC and the TiAl, Ni/TiAl or Ge/TiAl contact materials were made using cross sectional

high resolution transmission electron microscope. The interfacial microstructure analysis indicated that the reduction of the annealing temperature was obtained due to enhancement of the carbide layer formation by increasing the chemical reactivity between the **SiC** and the contact materials.

#### Descriptors

ALUMINIUM; ANNEALING; CRYSTAL-MICROSTRUCTURE; ELEMENTAL-SEMICONDUCTORS; GERMANIUM; INTERFACE-STRUCTURE; NICKEL; OHMIC-CONTACTS; SEMICONDUCTOR-EPITAXIAL-LAYERS; SILICON-COMPOUNDS; TITANIUM; TRANSMISSION-ELECTRON-MICROSCOPY; WIDE-BAND-GAP-SEMICONDUCTORS.

#### Classification codes

A6170A Annealing-processes;  
A6855 Thin-film-growth-structure-and-epitaxy;  
A6480G Microstructure;  
A6848 Solid-solid-interfaces;  
B2550A Annealing-processes-in-semiconductor-technology\*;  
B2530D Semiconductor-metal-interfaces;  
B2520C Elemental-semiconductors.

#### Keywords

ohmic-contact-materials; **wide-gap-p-type-4H-SiC**; TiAl-ohmic-contacts; annealing; ohmic-contact-formation; thin-Ni-layer; thin-Ge-layer; interfacial-microstructure-analysis; cross-sectional-high-resolution-transmission-electron-microscopy; carbide-layer-formation; 200-degC; 400-degC; 10-hr; **SiC-Ti-Al**; **SiC-Ni-Ti-Al**; **SiC-Ge-Ti-Al**.

#### Treatment codes

X Experimental.

#### Numerical indexing

temperature: 4.73E02 K.  
temperature: 6.73E02 K.  
time: 3.6E04 s.

#### Chemical indexing

**SiC-Ti-Al-int**, **SiC-int**, Al-int, Si-int, Ti-int, C-int, **SiC-bin**, Si-bin, C-bin, Al-el, Ti-el.  
**SiC-Ni-Ti-Al-int**, **SiC-int**, Al-int, Ni-int, Si-int, Ti-int, C-int, **SiC-bin**, Si-bin, C-bin, Al-el, Ni-el, Ti-el.  
**SiC-Ge-Ti-Al-int**, **SiC-int**, Al-int, Ge-int, Si-int, Ti-int, C-int, **SiC-bin**, Si-bin, C-bin, Al-el, Ge-el, Ti-el.

#### Language

English.

#### Publication type

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## Ternary TiAlGe ohmic contacts for p-type 4H-SiC.

#### Dialog eLinks

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**Source**

Journal of Applied Physics, [J-Appl-Phys-USA], 15 Feb. 2004, vol. 95, no. 4, p. 2187-9, 15 refs, CODEN: JAPPAU, ISSN: 0021-8979. Publisher: AIP, USA.

**Author(s)**

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**Author affiliation**

Sakai, T., Nitta, K., Tsukimoto, S., Moriyama, M., Murakami, M., Dept. of Mater. Sci. & Eng., Kyoto Univ., Japan.

**Abstract**

Reduction of annealing temperature to prepare low resistance ohmic contact materials for p-type 4H-SiC was achieved by adding Ge to the conventional TiAl contacts. Although the binary TiAl contact is required to anneal at temperature as high as 1000°C to convert Schottky to ohmic behavior after deposition of the Ti and Al layers on the SiC substrate, the GeTiAl contacts provided the specific contact resistance of about  $1 \times 10^{-4}$   $\Omega$  cm<sup>2</sup> by annealing at temperature as low as 600°C. This low annealing temperature is desirable to reduce the gate leakage current of the SiC devices. The GeTiAl ohmic contacts were thermally stable during isothermal annealing at 400°C subsequently after preparing the ohmic contacts by annealing at 600°C, which is also required by the device packaging process.

**Descriptors**

ALUMINIUM-ALLOYS; ANNEALING; CONTACT-RESISTANCE; ELECTRON-BEAM-DEPOSITION; GERMANIUM-ALLOYS; LEAKAGE-CURRENTS; OHMIC-CONTACTS; SEMICONDUCTOR-EPITAXIAL-LAYERS; SEMICONDUCTOR-METAL-BOUNDARIES; SILICON-COMPOUNDS; THERMAL-STABILITY; TITANIUM-ALLOYS; VACUUM-DEPOSITION; WIDE-BAND-GAP-SEMICONDUCTORS.

**Classification codes**

A7340N Electrical-properties-of-metal-nonmetal-contacts\*;  
A7340C Contact-resistance-contact-potential-and-work-functions;  
A8115G Vacuum-deposition;  
A6855 Thin-film-growth-structure-and-epitaxy;  
A7360P Electrical-properties-of-other-inorganic-semiconductors-thin-films-low-dimensional-structures;  
B2530D Semiconductor-metal-interfaces\*;  
B0520D Vacuum-deposition;  
B2520M Other-semiconductor-materials.

**Keywords**

ternary-TiAlGe-ohmic-contacts; annealing-temperature; low-resistance-ohmic-contact-materials; Ge-addition; binary-TiAl-contact; SiC-substrate; specific-contact-resistance; gate-leakage-current; isothermal-annealing; ohmic-contacts; device-packaging-process; 400-degC; 600-degC; 1000-degC; SiC-TiAlGe.

**Treatment codes**

X Experimental.

**Numerical indexing**

temperature: 6.73E02 K.  
temperature: 8.73E02 K.  
temperature: 1.27E03 K.

**Chemical indexing**

SiC-TiAlGe-int, TiAlGe-int, SiC-int, Al-int, Ge-int, Si-int, Ti-int, C-int, TiAlGe-ss, Al-ss, Ge-ss, Ti-ss, SiC-bin, Si-bin, C-bin.

**Language**

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**Publication type**

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**Availability**

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## Search Strategy

No.	Database	Search term	Info added since	Results
1	INZZ	tsukimoto-\$.AU.	unrestricted	81
2	INZZ	1 AND sic	unrestricted	10

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